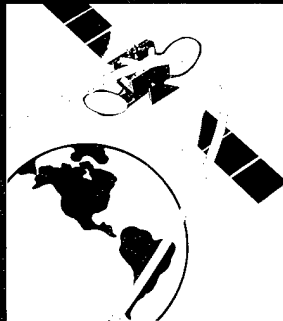


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# **FOREWORD**

## **THE LEGACY OF SDI RESEARCH**

For the past five years of the SDI program, over \$16 billion has been invested in the research and development of new technology that can make the world a safer place to live. While this investment has been made for the common defense and has made great strides forward, it has also developed a wave of new technology with applications to almost every imaginable scientific discipline ranging from medicine to the preservation of the global environment.

This document reports on the progress of the new state-of-the-art technologies that are the products of the SDI investment and their contributions to the national technology base, the economy, and the challenge of international competitiveness. The SDI program established its Technology Applications Program in conjunction with Congressional and Presidential initiatives that recognize the necessity of making federal technology available to American industry within the constraints of national security considerations. This report details the program that has been structured to carry out these tasks, and its ongoing activities. The SDI technological legacy is detailed in terms of the spinoffs and new businesses created by applying SDI technologies to medical, computer, energy, electronics, aerospace, automotive, and other industrial applications.

# CHAPTER I

## INTRODUCTION

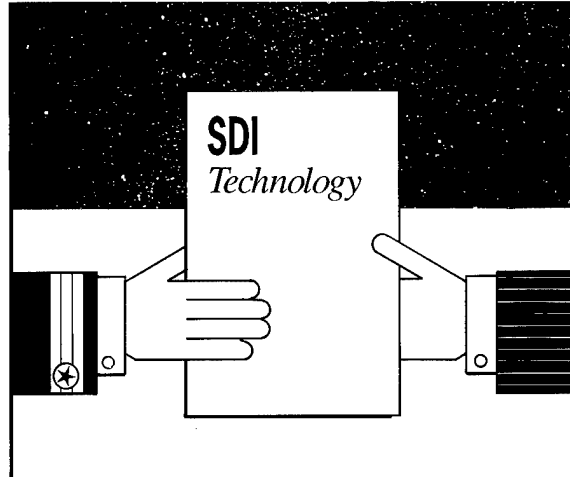
### A. PURPOSE OF REPORT

This report is provided to inform its reader of the Strategic Defense Initiative Organization's (SDIO) efforts to facilitate the transfer of Strategic Defense Initiative (SDI)-developed technology to the private sector, federal agencies, state and local governments, and universities. These SDIO-initiated activities are designed to comply with Congressional and Presidential direction and guidance enacted to provide entrepreneurs, scientists, academicians, and researchers greater access to federally-funded research and development (R&D) for use in the research, development, and commercialization of new products and processes. Technology transfer legislation includes *The Stevenson-Wydler Technology Innovation Act of 1980*, *The Bayh-Dole University and Small Business Patent Procedure Act of 1980*, *The National Cooperative Research Act of 1984*, and *The Federal Technology Transfer Act of 1986*. Other technology transfer direction that set this precedent are *The National Defense Act of 1987*; Executive Order 12591 of April 1987, "Facilitating Access to Science and Technology"; *The Omnibus Trade and Competitiveness Act of 1988*; and *The National Competitiveness Technology Transfer Act of 1989*. Information detailing these initiatives is provided in this report's Chapter II, "Background."

The goal of SDIO's technology transfer efforts is to make SDI research, conducted to develop a strategic defense system (SDS) against intercontinental ballistic missiles, available as a source to:

- Develop and commercialize new or improved U.S. private sector products and production techniques to bolster U.S. productivity and its competitive position in the international marketplace;
- Fulfill other Department of Defense (DOD) program R&D requirements; and
- Supplement R&D done by other U.S. government agencies, universities, and research organizations.

SDIO works to facilitate this technology transfer process through an SDI Technology Applications Program and



other technology transfer programs established to:

- Identify potential private and public sector applications for SDI-developed technologies;
- Provide information about SDI-developed technologies to U.S. corporations, small businesses, universities, entrepreneurs, and federal, state, and local government agencies and facilitate the interchange between the seekers of

technology and those who hold it; and

- Institute measures to provide the type of information that will accelerate the technology transfer process while protecting the disclosure of sensitive technology data or the infringement of an individual or organization's intellectual property rights.

### B. SDI AND TECHNOLOGY TRANSFER

DOD has historically played a pivotal role in fostering the development of many new technologies which have impacted the civilian economy and the United States' competitive standing in the international marketplace. DOD-funded SDI research provides such an opportunity since it is redefining what is considered state of the art in a vast array of new and emerging areas. Because the approach to identify technologies for the SDS is broad in scope, SDI-funded R&D serves as a source of technological innovation for other U.S. research, development, and commercialization efforts. SDI research, for instance, has spawned spinoffs in medicine, computer technology, materials science, optics, sensor technology, energy, and semiconductor technology. It has also served as a catalyst for spinoffs in superconductivity, communications, lasers, industrial manufacturing processes, electronics, and microwave technology.

SDIO's role in the technology transfer process is to act as a facilitator that brings potential technology users—those individuals with a requirement that can be met with an SDI-funded technology—together with the technology's supplier, the inventor or organization that originally developed the SDI technology. Operating within the established policies for national security and export

control, SDIO identifies potential secondary applications for emerging SDI technologies and then provides information about these technologies to U.S. private and public sector individuals and organizations that can use the SDI technologies for other purposes.

The success or failure of transferring these SDI-developed technologies to potential users, however, depends on more than providing information to initiate business deals for use of these technologies. It also depends on a number of other factors outside the purview of SDI such as the funding secured to underwrite product development and the market within which an entrepreneur or organization will introduce the newly-developed product or process.

Notwithstanding the influence of these factors on the technology transfer process, SDIO has taken a critical first step in moving SDI-developed technologies to the marketplace or for use in other R&D efforts. It has done

this by providing the type of information to facilitate the person-to-person interaction essential to transfer SDI technology from its supplier—the inventor or developer—to its potential new users: entrepreneurs, investors, and researchers.

### **C. ORGANIZATION OF REPORT**

This report examines initiatives SDIO has taken to facilitate the SDI technology transfer process. Chapter II discusses the importance of technology transfer to the nation and the challenges that must be addressed in transferring certain SDI-developed products and processes which are categorized as militarily critical technologies. This is followed in Chapter III by a description of SDIO technology transfer activities. Chapter IV concludes this report with a representative sample of American spinoffs spawned by SDI-funded research.



## CHAPTER II

### BACKGROUND

#### A. INTRODUCTION

DOD R&D's primary goal is to build and strengthen the technology base and military infrastructure critical to support U.S. defense missions. At the same time, though, DOD-sponsored R&D can also act as a catalyst to benefit the U.S. economy.

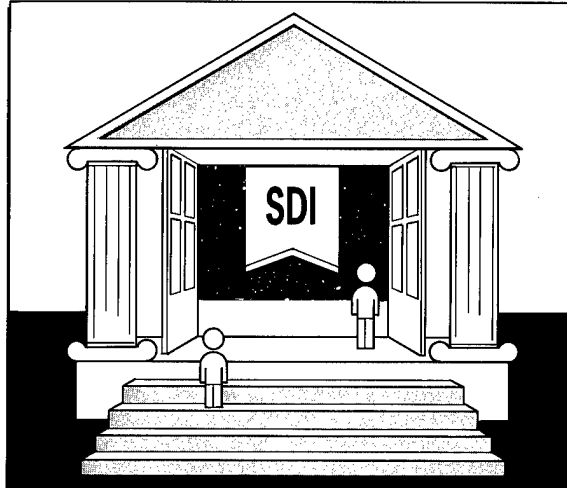
Recognizing this relationship, the federal government has enacted technology transfer initiatives since the early 1980s that provide entrepreneurs, scientists, academicians, and small business greater access to DOD-developed technologies for use in the R&D and commercialization of new products and processes. Even with the emphasis of these Congressional and Presidential initiatives, the process by which DOD-funded technologies are transferred to the U.S. private and public sectors is fraught with obstacles that litter the path by which a DOD innovation can be moved from the laboratory to the marketplace or used to supplement other R&D efforts. If not addressed, these obstacles may stifle a national source of scientific and technical talent that, if released, would otherwise serve as a source of innovation to improve U.S. productivity and competitiveness in the international marketplace.

#### B. NATIONAL TECHNOLOGY TRANSFER INITIATIVES

Congressional and Presidential initiatives have been enacted since the early 1980s that make technology transfer an instrument of national policy. Information about these initiatives is included in Table 1.

*The Federal Technology Transfer Act of 1986*, for example, states that "technology transfer, consistent with mission responsibilities," is to be the "responsibility of each laboratory science and engineering professional." This public law also directs "each laboratory director" to "ensure that efforts to transfer technology are considered positively in laboratory descriptions, employee promotion policies, and the evaluation of job performance of scientists and engineers in the laboratory."

This act also provides financial incentives to encourage federal scientists and engineers to patent, license, and



commercialize their research. These incentives include royalty-sharing arrangements and government waiver of ownership to inventions made with federal funds. This act also promotes the participation of private companies in cooperative R&D agreements (CRDAs) by allowing laboratory directors to negotiate the CRDAs directly.

Taking this process a step further, *The National Defense Authorization Act of 1987* states that the Secretary of

Defense shall "encourage to the extent consistent with national security objectives, the transfer of technology between laboratories and research centers of the Department of Defense and other federal agencies, state and local governments, colleges and universities, and private persons in cases that are likely to result in the maximum use of such technology."

#### C. THE NEED FOR DOD TECHNOLOGY TRANSFER

The technical talent and know-how that can be unharassed through these technology transfer initiatives will become especially important as the United States enters the 1990s. The United States begins the new decade facing many economic challenges from abroad. Though the primary goal of DOD-funded R&D is to support and strengthen the U.S. military infrastructure in its defense missions, the results yielded from that R&D can also serve as a source of innovation to maintain and strengthen U.S. productivity and competitiveness in the international marketplace.

A number of statistics indicate that the United States is losing its competitive edge in global markets. According to Department of Commerce figures, for example, almost half of all patents filed with the U.S. Patent and Trademark Office in the past three years were issued to foreign corporations.

This trend could have serious ramifications for the United States, especially as it becomes more dependent on foreign suppliers for its defense system components. According to one recently released Defense Resources

## FEDERAL TECHNOLOGY TRANSFER LEGISLATION AND EXECUTIVE ORDERS

<b>The Stevenson-Wydler Technology Innovation Act of 1980</b>	This law established and funded Offices of Research and Technology Applications at major federal laboratories to identify and provide information on technologies to private industry, universities, and state and local government for use in other R&D or commercialization efforts. This act also established the Center for the Utilization of Federal Technology which is now housed at the National Technical Information Service.
<b>The Bayh-Dole University and Small Business Patent Procedure Act of 1980</b>	This law allowed small firms and universities to obtain title to inventions funded by the federal government.
<b>The Small Business Innovation Development Act of 1982</b>	This law mandated that federal agencies develop small business innovation research programs and establish specific goals for the participation of small businesses and minority, disadvantaged organizations in contracts, grants, and CRDAs.
<b>The National Cooperative Research Act of 1984</b>	This law permitted consortia of companies that have proper registration with the Department of Commerce to engage in joint R&D ventures without violating anti-trust laws. The law did not, however, permit co-production.
<b>The Federal Technology Transfer Act of 1986</b>	This law granted government laboratory directors authority to enter into CRDAs with for-profit corporations, assign patent rights to firms participating in CRDAs, and license technologies. The act also provided for the retention of licensing royalties by government laboratories and mandated that a minimum 15 percent of royalties on federal patents be awarded to federal inventors. Furthermore, the act also institutionalized and funded the Federal Laboratory Consortium for Technology Transfer with a charter to transfer technology from the federal laboratories to industry, universities, and state and local governments.
<b>The National Defense Authorization Act of 1987</b>	Provisions in this act encouraged the Secretary of Defense to transfer DOD-developed technology to other U.S. private and public sector organizations and individuals to the extent that it is consistent with national security objectives. The act also called for the Secretary to examine and implement methods to enable DOD personnel to promote technology transfer.
<b>Executive Order 12591 "Facilitating Access to Science and Technology"</b>	This executive order, enacted by the President in April 1987 to promote the commercialization of science and technology, calls on the Secretary of Defense to identify new technologies that would be potentially useful to U.S. industries and universities and accelerate efforts to make the technologies more readily accessible to those users.
<b>The Omnibus Trade and Competitiveness Act of 1988</b>	This law changed the National Bureau of Standards' name to the National Institute of Standards and Technology (NIST) to reflect NIST's new charter which broadened its role from developing/disseminating measurement standards and scientific data to promoting the commercialization and transfer of federally-developed technology to private industry and state and local government. The act also initiated regional centers for transfer of manufacturing technology; made provisions to assist state technology extension programs; and established a clearinghouse for state and local initiatives on productivity, technology, and innovation.
<b>The National Competitiveness Technology Transfer Act of 1989</b>	<p>This law granted contractor-operated federal laboratories the authority to enter into CRDAs and license technologies. It also established time frames to accelerate government negotiations for entering into CRDAs while exempting CRDAs from Freedom of Information stipulations for up to five years.</p> <p>Setting a similar tone, Executive Order 12591 directed the Secretary of Defense to "identify a list of funded technologies that would be potentially useful to the United States industries and universities" and then "accelerate efforts to make these technologies more readily accessible to industries and universities."</p>

Board report, 20 critical weapon systems have been identified with electronic suite components that are predominantly foreign made and unavailable from domestic manufacturers. Similarly, U.S. sales in European defense markets dropped by more than 60 percent between fiscal years 1983 and 1987 while U.S. defense-related purchases in Europe during the same period increased by more than 125 percent.

Added to these trends are statistics indicating an erosion of the U.S. manufacturing base. Advanced manufacturing, an element critical to moving a technology from basic and applied research to prototype and product development, represents a capital-intensive investment, both in the training of skilled workers and in the physical plants to manufacture the products. This is one area where, for the first time since World War II, Japan, which has a smaller economy, is out-investing the United States in both equipment and facilities. According to Department of Commerce figures for 1989, after two years of double-digit growth in capital investment, Japanese businesses are expected to increase their spending on equipment and new facilities by more than ten percent again. U.S. business managers, by contrast, are forecasting a 4.9 percent increase, according to the Commerce Department.

Recognizing these trends, a House of Representatives Committee on Science, Space, and Technology report, *Technology Policy and its Effect on the National Economy*, released last year states, "At a time when the United States has a large trade deficit, the Task Force encourages the DOD to use its research and development resources to promote commercial applications whenever possible."

## **D. CHALLENGES TO THE TECHNOLOGY TRANSFER PROCESS**

Though DOD-funded R&D is a good source of innovation, the process used to move the emerging technology from research through development may be fraught with challenges. Among these challenges are security considerations, institutional barriers, intellectual property issues, and other factors complicating DOD efforts to transfer federally-developed technology to the U.S. private sector.

### **1. Security Considerations**

Classified programs hinder technology transfer efforts by creating a mind-set that all elements and technical developments within a classified program are also unequivocally classified. It may, however, be more appropriate for the subsystem and components—or perhaps the processes used to create them—to be properly protected but not necessarily through classification.

For example, designation as a militarily-critical or export-controlled technology can facilitate the transfer of tech-

nology domestically while protecting the technology from leaking off shore without proper export control. Access to militarily-critical and export-controlled technology is available to more than 15,000 U.S. contractors and citizens under a militarily-critical technology certification process established by DOD under *The National Defense Authorization Act of 1984*. This certification program was established to stem the flow of military-related technical data without blocking the exchange of technical information that U.S. industry or academia can use for legitimate domestic or foreign business and research purposes.

This certification is available to anyone who is a U.S. citizen and working for an organization or enterprise requiring such information to bid on a contract with DOD or another federal agency, perform work on such a contract, or engage in other legitimate activities such as scientific research or the selling and manufacturing of products for domestic and foreign commercial markets. To participate in this program, the individual or organization must sign a binding agreement, under penalty of law, not to release the requested materials to foreign nationals without an approval, authorization, or license under U.S. export-control law. Thus, while national security is an important consideration in technology transfer, unnecessary classification should not be substituted for export control provisions that can better restrict the improper use of technology while permitting its use for other legitimate efforts. (See sidebar on following page)

### **2. Intellectual Property Issues**

The most significant barrier to technology transfer for the inventor is the potential loss of intellectual property rights. Therefore, one of the most challenging aspects in developing a technology transfer relationship is a clear determination and agreement of how to deal with the disclosure of intellectual property information. Compounding this problem are inconsistent federal laboratory and agency policies that frequently create the perception among entrepreneurs that once they have developed a patentable product or process they lose their intellectual property rights to the government. Congress has issued a series of statutes to correct this problem by giving laboratories the authority to license technology that generate royalties and to enter into CRDAs which are exempted from freedom of information disclosure requirements for up to five years.

### **3. Institutional Barriers**

A number of barriers inherent to the DOD acquisition process frequently serve as disincentives to the technology transfer process. DOD laboratory directors and program managers are sometimes prone to protect their R&D budgets and do not actively seek to use technology developed with alternative funds for fear that it might

lead to the erosion of their R&D budget or management authority. Similarly, defense contractors frequently are not incentivized to use emerging technology in their system design and development work. They often propose conservative development programs where the R&D costs and risks are lower. While this conservative management approach might be appropriate in many instances, each case must be evaluated individually by both government and contractor personnel who are fully aware of relevant technology capabilities and maturity. Unfortunately, this situation is often the exception rather than the rule in defense acquisition.

#### **4. Other Factors**

In addition to challenges emanating from international competition and DOD technology transfer barriers, another challenge that must be faced is the philosophical gap between the missions of the federal scientific and technical community that does the R&D work and the motivations of the private sector companies and entrepreneurs who would invest in the results of that work.

Being technologically-driven organizations, the federal laboratories and scientific and technical centers make large investments in R&D facilities and have a primary interest in achieving and maintaining technological superiority. Given these goals, they establish a technology base and develop enabling technology long before they have a product or systems application.

Being market-driven, by contrast, private sector companies and entrepreneurs tend to analyze current and secondary markets to predict the types of products that will yield a profit. Based on these analyses, they then develop focused product concepts and prototypes and make the required investments for manufacturing and production.

Because federal R&D centers and private companies operate using different assumptions and orientations, they frequently talk at each other rather than to each other in terms of technology transfer and commercialization. For this reason, technology brokers and public sector intermediaries are becoming increasingly important players in the technology transfer process.

#### **E. BRIDGING THE TECHNOLOGY TRANSFER GAP**

Access to information is an essential element in the technology transfer process. It is the way researchers, investors, and other interested parties discover what DOD-developed technologies are available for transfer. Challenges that interfere with the flow of scientific and technical information make it difficult to establish the necessary lines of communication to transfer technology.

#### **Applying for Certification to Receive Militarily Critical Technology Data**

*The Defense Logistics Agency has overall responsibility for administering the militarily critical technology certification system, and the Defense Logistics Agency, located in Battle Creek, Michigan, carries out the operational functions. The interested party seeking certification submits a DD Form 2345, "Militarily Critical Technical Data Agreement," to the Commander, Defense Logistics Service Center, Attention: DLSC-FBA, Federal Center, Battle Creek, Michigan, 49017-3084. The Center will respond to questions concerning completion of the form. Telephone inquiries can be made by calling the Defense Logistics Center toll free at 800-DLA-DLSC.*

*Companies that are certified will be assigned a certification number and will be eligible to receive export-controlled DOD technical data for a renewable five-year period.*

*Once certification has been approved, the interested party is eligible to access the SDI Technology Applications Information System (TAIS), a technology transfer database referral system with more than 1,300 unclassified, nonproprietary abstracts describing SDI technologies that can serve as potential investment opportunities or supplement ongoing R&D activities. Information about the TAIS can be found on pages 14 and 15.*

Bridging this communication gap requires person-to-person interaction that unite a technology's potential users with the technology's supplier, the inventor or organization that originally developed the technology. Such connections are needed to discuss technical details and make business arrangements to use the technology for other applications.

Building on these principles and in response to Congressional and Presidential guidance to facilitate the DOD technology transfer process, SDIO established the Office of Technology Applications to make SDI technologies available to the U.S. private and public sectors. SDIO

does this by identifying and cataloguing emerging SDI technologies with potential private and public sector R&D or commercial applications. SDIO then provides individuals and organizations who participate in DOD's militarily critical technology certification program (see pages 8 and 9) access to information about SDI technology, so they can contact the technology's developer to establish mutual interests in moving the technology from the laboratory to the marketplace or in using it to supplement other R&D efforts. SDIO's Technology Applications Program and other technology transfer efforts initiated by SDIO are described in Chapter III.

# CHAPTER III

## SDI TECHNOLOGY TRANSFER PROGRAMS

### A. INTRODUCTION

The SDI Technology Applications Program, established in response to congressional and presidential technology transfer initiatives, is designed to make SDI-funded technology available as a source of innovation used by:

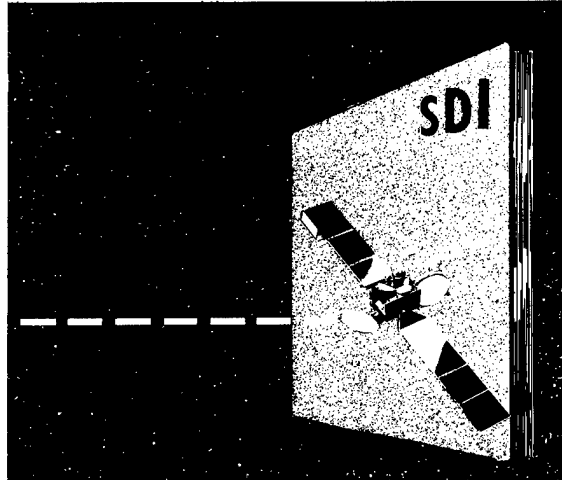
- Entrepreneurs and private sector companies to develop marketable new or improved products or production techniques to bolster U.S. productivity and its competitive position in global markets;
- Other DOD and federal programs to fulfill their R&D requirements;
- Universities and researchers to expand their basic or applied research; and
- State and local agencies in their government operations and regional economic development efforts.

The SDI Technology Applications Program works to facilitate the technology transfer process by providing information about SDI-funded technologies to the above users. This information is provided so that they will contact the technologies' inventors and suppliers to discuss technical information and business arrangements that will facilitate the SDI technology transfer process.

### B. SDI TECHNOLOGY APPLICATIONS PROGRAM ACTIVITIES

#### 1. Introduction

The SDI Technology Applications Program uses several approaches to encourage person-to-person contact: technology-push and requirements-pull mechanisms of technology transfer. The technology-push mechanism identifies technologies which have already been developed for SDI and provides the interested party information on those technologies. This is done so that the requestor can contact the technologies' developers to determine whether the emerging SDI technologies of interest can be used in the R&D or commercialization of new products or processes. Evaluating such factors as consumer demand and industrial, manufacturing, and



military needs, the requirements-pull mechanism is designed to match non-SDI technology requirements with a set of SDI technologies that can be integrated or customized to meet those requirements. Requirements-pull looks at outside requirements for technology and then searches for SDI technologies which may meet those requirements.

#### 2. Technology-Push Features of the SDI Technology Applications Program

Technology-push methods of transfer adopted by the program include the SDI TAIS, a technology transfer database referral system that contains more than 1,300 unclassified, nonproprietary abstracts describing SDI technologies in such areas as superconductivity, sensors, lasers, supercomputers, advanced materials, and industrial processes. Entrepreneurs and researchers can access the TAIS by computer modem to identify potential investment opportunities, supplement R&D activities, or move an emerging technology from the laboratory to the marketplace. The TAIS also provides other nontechnical information vital to the technology transfer process such as:

- Information on resources and technology transfer services provided by more than 175 federal and 470 state and regional business assistance agencies nationwide;
- Business opportunities available through the SDI SBIR and innovative science and technology programs. These programs provide funding for innovative R&D applicable to SDI requirements; and
- Information about SDI MODILs established to develop manufacturing capabilities to meet SDI requirements for which current industrial capabilities are insufficient.

Once the user has identified those technologies from the TAIS for which more information is desired, SDIO works as an intermediary to link the user with the SDI researcher or developer of those technologies and then tracks the results of the ensuing communication to see what additional assistance can be provided. Through

these efforts, SDIO facilitates the person-to-person contact needed to transfer technology.

### **3. Requirements-Pull Features of the SDI Technology Applications Program**

#### **a. Introduction**

The requirements-pull features of the SDI technology applications program stress the importance of networking to identify potential private sector markets and governmental programs that can use SDI-developed technology spinoffs. These networking tools include SDI technology applications reviews and the Joint SDI-Defense Applications Initiative (JDAI) panel.

#### **b. SDI Technology Applications Reviews**

SDIO sponsors reviews by scientific and technical experts and commercialization specialists from universities, federal laboratories, private research institutes, corporations, and professional associations to help identify government and commercial applications for SDI technologies. These specialists meet at regularly-scheduled technology applications reviews to assess the potential technological and economic impact of SDI R&D, discuss potential new applications of the technology, and identify ways to accelerate the transfer and commercialization process. Specific areas in which these technology applications reviews focus include: the identification and evaluation of SDI technology transfer opportunities in biomedical applications; optics technologies; materials and industrial processes; electronics, computer technology, and communications; as well as power generation, storage, and transmission.

#### **c. The Joint SDI-Defense Applications Initiative (JDAI) Panel**

The JDAI panel resulted from a 1987 DOD Defense Planning and Resource Board study recommending establishment of a mechanism to identify SDI technologies that meet other DOD R&D requirements. This is done by familiarizing panel members with the SDI technology base and introducing them to methodologies available to cross-match DOD technology needs with potential solutions from SDI research. DOD programs examined through this process include the Air Defense Initiative, the Balanced Technology Initiative, strategic force modernization, space and conventional defense systems, as well as science and technology programs.

The TAIS is the primary tool used in this cross-matching process. The TAIS is designed to allow the user to review generic categories of SDI-funded technologies and link various technologies with potential defense applications. The TAIS uses DOD-identified militarily critical technologies as a standard lexicon to cross-match user requirements with available technologies and also has a keyword search capability.

The JDAI panel also serves as a vehicle for DOD R&D program managers to make classified information requests and to establish new or more effective lines of communication with each other. Additionally, the panel serves as a mechanism to expedite the process by which information about SDI technologies is made available to support other DOD activities.

### **C. OTHER SDIO TECHNOLOGY TRANSFER ACTIVITIES**

#### **1. Introduction**

In addition to activities discussed above, SDIO is facilitating the technology transfer process through other ongoing program initiatives.

#### **2. The SDI Medical Free Election Laser (MFEL) Program**

The MFEL Program was established at the direction of Congress in 1985 to establish medical centers to adapt FEL technology to applications in medicine, photobiology, surgery, and materials science. The MFEL Program is national in scope and draws upon the resources and expertise of more than 20 universities and teaching hospitals to further FEL research.

This research focuses on FELs because they can achieve higher, more controllable peak power levels than conventional lasers and do so at a much higher efficiency, a critical factor in generating high-powered laser energy. FELs can also be tuned over a wide range of wavelengths in contrast to conventional lasers which usually work at fixed wavelengths. Tunability and precise control of power output combine to give FELs unprecedented utility.

It is this utility which makes the FEL so promising a tool for use in medical, biophysical, and materials research. Because it can operate across a wide range of wavelengths and power levels, the FEL can be tuned to the desired wavelength needed, for example, to cut tissue and bone more effectively than current surgical lasers. Because its wavelength can be varied, the FEL can also be used by material scientists to probe and study materials for thermal and photochemical reactions and by biophysicists to study the physiological responses of biological materials.

#### **3. Miniature Accelerators for Positron Emission Tomography (PET)**

Another program directed in the 1989 Congressional language aims to advance the technology and availability of radiopharmaceuticals for PET, a noninvasive medical imaging technology that produces false color images of metabolic activity in the living body. While PET capability is presently available at a limited number of facilities nationwide, the cost, size and shielding requirements of

the large cyclotrons used to make the trace elements (radio pharmaceuticals) for PET have precluded widespread availability.

Under SDIO leadership, development contracts have been awarded to develop small, light weight, low cost accelerators used to produce the radio pharmaceuticals required for the PET imaging technique. The key to the miniaturization of these accelerators comes from SDI research which has reduced radio frequency linear accelerator sizes from that of a three-story building to one that can be placed on a table top.

#### **4. The SDI Small Business Innovation Research (SBIR) Program**

The SDI SBIR Program was established in compliance with *The Small Business Innovation Development Act of 1982* to encourage the participation of small businesses in contracts and grants awarded by SDIO. Under this program's provisions, SDIO will award small high technology companies an average of \$50,000 in Phase I funds to explore the feasibility of developing an innovative idea into a product or process that supports the SDI mission. Those SBIR projects with the most technical merit and feasibility can then be awarded a follow-on \$500,000 Phase II contract to develop the innovation into a prototype process or product and bring it to market. The evaluation process for both Phase I and Phase II SBIRs includes potential commercialization of the process as well as the SDI application.

SDI SBIR-funded efforts are described in the TAIS to facilitate SBIR Phase III commercialization efforts. Phase III activities focus on the pursuit by the small business of

its SBIR Phase I and Phase II research results using non-federal capital for commercial applications or continued government support for either further research or acquisition of end products for federal use.

#### **5. SDI Manufacturing Operations Development and Integration Laboratories (MODILs)**

SDIO has established MODILs to work with industry, universities, and the federal laboratories to develop SDI component manufacturing capabilities based on emerging technologies yielded from research done by the larger scientific and technical community. These laboratories do this by:

- Searching for emerging technologies that are key to the development and manufacturing of SDS components;
- Accelerating the development and transfer of high-payoff technologies for which current industrial manufacturing capabilities are insufficient; and
- Establishing an industrial base for SDI technologies.

#### **D. SUMMARY**

The SDI Technology Applications Program—in conjunction with other SDIO technology transfer activities such as MODILs and the SDI MFEL, PET, and SBIR programs—provide services to accelerate the transfer of SDI-funded technologies to the U.S. private and public sectors. These services are provided to encourage the dialogue between the developers of SDI technology and those individuals and organizations that can use the technology in other scientific, technical, and commercial products or processes.

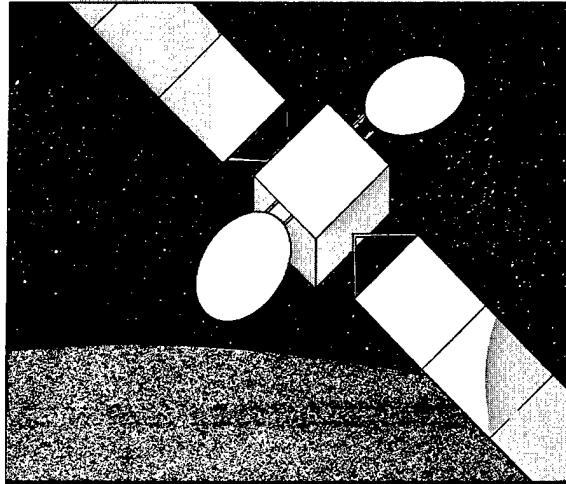


# CHAPTER IV

## SDI SPINOFFS

### A. INTRODUCTION

SDI-sponsored research is serving as a catalyst for spinoffs in many scientific and technical fields. Spinoffs, for example, have been spawned in medicine, computer technology, electronics, aerospace innovations, optics, automotive engine components, as well as industrial and manufacturing processes. Representative spinoffs in each of these areas are presented in this chapter.



### B. SDI SPINOFFS IN MEDICINE

#### 1. Introduction

SDI-sponsored research in laser technology, materials science, and high-energy physics has yielded a number of innovations of value to the medical community. These include developments in biomedical research; eye surgery; materials that produce lighter, stronger leg braces; and cancer therapy.

#### 2. Lasers in Medicine

SDI laser work is yielding promising results as a tool for biomedical research. Because it can operate at such a wide range of wavelengths and power levels, the FEL and other SDI-funded laser developments can be used for photodynamic therapy, a process in which a FDA approved photochemical dye when absorbed by specific types of living cell tissue and then subjected to a specific wavelength of light causes a specific chemical change. This photodynamic process can be used to treat or precisely destroy tumors and viral contaminants. This process has yielded a number of breakthroughs:

- Bone marrow purging is now being used to treat leukemia remissions. In this technique, infected bone marrow is removed from the patient, injected with a dye that is absorbed by the leukemia cells, and then irradiated with a specific wavelength of light in the visible region which kills all the cancer cells while harming less than twenty percent of the healthy cells. After undergoing chemotherapy or radiation treatment, the patient then receives the purified photodynamic-treated bone marrow. This process is undergoing

clinical trials at the Baylor Research Foundation in Dallas, Texas.

- Experiments are being conducted to perfect a precision surgical technique that uses lasers to cut and cauterize organs simultaneously. This procedure is designed for precision excision of tumors which, under current clinical practice, would require surgical removal of the entire organ.

- The Baylor Research Foundation has been

awarded a patent that uses the photodynamic process to cleanse donor blood bank supplies of viral contaminants such as the entire family of viruses responsible for herpes, measles, hepatitis-B, and the human immunodeficiency virus that causes the acquired immunodeficiency syndrome (AIDS). In addition to funding provided by SDI for this blood bank purification process, the National Institutes of Health has awarded Baylor a grant to develop this process into a large-scale capability to be tested in 1991.

- Pharmaceuticals which have become useless in treating mutant strains of malaria are now being made effective once again through use of a newly-developed dye that causes the organism to succumb to the drug in the dye's presence.

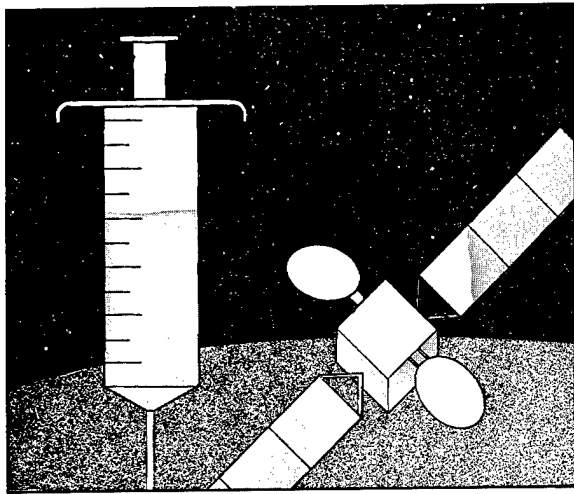
Expanding the scope of these projects, researchers at Baylor are collaborating with scientists and physicians from Australia, Canada, and the Federal Republic of Germany to identify and test other photodynamic dyes that can be used in photodynamic therapy to treat cancer, heart disease, and AIDS.

In addition to these developments in photodynamic therapy, procedures derived from SDI-sponsored laser research are being used to remove burn and scar tissue from the skin, fragment kidney stones, treat glaucoma and psoriasis, and remove tattoos without scarring.

#### 3. SDI Magnetic Suspension Technology Used in Cataract Surgery

Magnetic principles, originally used by Aura Systems, Inc. of Los Angeles, California, to develop a magnetic

suspension stand to test SDI rocket thrusters, are now being used to develop surgical techniques for cataract removal. Using this procedure known as the Kelman Electromagnetically-Assisted Surgical Technique (KELMAST), the surgeon takes a syringe and injects a tiny magnetic bead into the cataract. The surgeon then uses an Aura-developed instrument to control the magnetic bead as it pulverizes and emulsifies the cataract. Both the cataract particles and magnetic bead are withdrawn by syringe and a silicon- or collagen-based liquid compound is injected into the intact lens capsule to form a new lens.



The KELMAST procedure and KELMAST surgical apparatus are undergoing further R&D. Actual use on medical patients is projected within two years after extensive testing on animals and approval by the Food and Drug Administration.

#### 4. SDI-Funded Microlasers Used in Medicine and Other Commercial Applications

SDI-funded microlaser technology developed at the Massachusetts Institute of Technology's (MIT) Lincoln Laboratory, Lexington, Massachusetts, may soon be available as a high value-added innovation for laser medicine as well as commercial products and processes used in micromachining, testing and inspection, telecommunications, and optical information storage.

Microlasers represent a new class of miniaturized, all-solid-state laser devices based on the emerging technology of diode-laser pumping of solid-state crystal. The advantages of these new microlasers range from improved performance that has been unattainable with many earlier lasers to greater ease of manufacturing.

Compared to gas-discharge lasers, microlasers offer improved reliability, compactness, and greater efficiency. These advantages permit microlasers to address research and industrial problems that cannot be served by conven-

tional laser technology.

Gas-discharge lasers, for example, use gas-filled glass tubes that are fragile, labor-intensive to manufacture, and typically last a few thousand hours or less. Microlasers, by contrast, are made of an all-solid-state construction that eliminates the glass tube, thereby making it more rugged, compact, and less sensitive to mechanical shock than gas-discharge lasers. Laboratory results indicate that microlasers also operate greater than ten times more efficiently than do gas-discharge lasers.

In addition, microlasers can be mass-produced easily at a low cost. Microlasers are designed with solid-state crystals and optics that are physically identical, except for the optical crystals. Microlaser components can, therefore, be interchanged to produce microlasers that emit radiation at different wavelengths.

Taking advantage of its ruggedness, efficiency, compactness, and the ease with which it can be manufactured, Lincoln Laboratory's microlaser technology can be used for a variety of purposes. These include:

- **Laser medicine and microsurgery:** Because it is a high-powered device that can be tuned to specific wavelengths, the microlaser has applications for cancer treatment, dermatology, and eye and heart surgery where microsurgical instruments and techniques are needed.
- **Manufacturing and military applications:** Compact, rugged, and reliable microlasers can be used to test and inspect semiconductor devices and optical fibers and optical communication components, and in robotics and machine control. They can also be integrated into range finders, target designators, guidance systems, and instrument alignment devices used by the U.S. military.
- **Telecommunications and optical disk storage:** The telecommunications industry can use Lincoln Laboratory's microlaser technology for a variety of applications, which include: projection displays (home TV and theater); instant photography techniques; color laser printers; and multiplexed fiber optical and computer data communications. Microlasers also have applications for optical storage systems that have a laser writing capability and that can read information on an optical disk.

#### 5. Materials for Stronger, Lighter Leg Braces

An advanced carbon-based composite material, originally developed for interceptors targeted to stop incoming enemy missiles, is now being used in prototype designs of leg braces for disabled persons. In order to demonstrate this application, Sparta, Inc. of La Jolla, California, designed and fabricated a prototype leg brace that, according to test results, is two times stronger, weighs

two-thirds less, and is forty percent more rigid than conventional leg braces made of steel.

With funds provided from the National Institute on Disability and Rehabilitation Research (NIDRR) under a joint SDIO-NIDRR project, Sparta is currently developing a design database and prototype designs for an advanced composite leg brace. Sparta is also planning a commercial development program to make these lightweight leg braces available to disabled individuals.

#### **6. Developments in High-Energy Physics Used for Cancer Therapy**

Radio frequency quadrupole linear accelerator (RFQ linac) technology developed at the Department of Energy's Los Alamos National Laboratory (LANL), Los Alamos, New Mexico, in response to SDI requirements for a neutral particle beam source, is now being used in cancer therapy treatment.

The RFQ linac, a device through which a beam of positively charged hydrogen or deuterium ions is accelerated to increase the energy of the particles, was tested at LANL in 1980. SDI requirements for this technology in directed energy space experiments led to miniaturization of the RFQ linac. This, in turn, has been key to enabling transfer of the RFQ linac technology to several commercial applications.

- The RFQ linac, modified by AccSys Technology, Inc., of Pleasanton, California, for use in other types of scientific and technical research, is being integrated into a proton therapy cancer treatment facility now being built by Loma Linda University Hospital in southern California. Three to five more facilities are also being planned in the next few years that use this technology.
- An accelerator for the production of radiopharmaceuticals used in the PET medical imaging and diagnostic tool, described earlier.
- A source of energy for a device to detect explosives in luggage.

See F2. for more information.

### **C. SDI SPINOFFS IN COMPUTER TECHNOLOGY**

#### **1. Introduction**

SDI research has been the source of a number of spinoffs in computer technology. Spinoffs from this research include new optical supercomputers, computer-aided design tools, components for optical computers, and the development of new computer security measures.

#### **2. A New Generation of Optical Supercomputers**

Optical technologies, such as holograms and lasers, are being combined with conventional electronics to produce

ultrafast, inexpensive supercomputers that process information 1,000 times faster than computers currently on the market. This technology, developed at the University of Alabama Center for Applied Optics, is being commercialized by the Nodal Corporation in Huntsville, Alabama. Having secured investment funds from private sector sources, Nodal Systems plans to produce its first optical computer components in 1992.

Research in optical computing is examining the differences in the behavior of optics and electronics and exploiting those differences to get around the bottlenecks caused by conventional hard-wired connections between chips. By exploring such phenomena as the reason why light beams cross through each other without causing interference while electronic signals cannot, optical computer research is evaluating the means to develop computer chips that could exchange data with one another extremely fast.

Estimates indicate that computer chips made with optical technology could process information 1,000 times faster than electronic technology. Optical computing technology can also be used to create a trillion interconnections which is more than the 10,000 found in most complex electronic processors. In addition, optical computers can operate at much lower power levels and can be designed to run on solar power.

Optical computing technology can be used to enhance the effectiveness of medical diagnostic systems that produce real-time images of human organs. It also has the potential to be incorporated into the design of machines to allow them to self-diagnose problems and repair themselves.

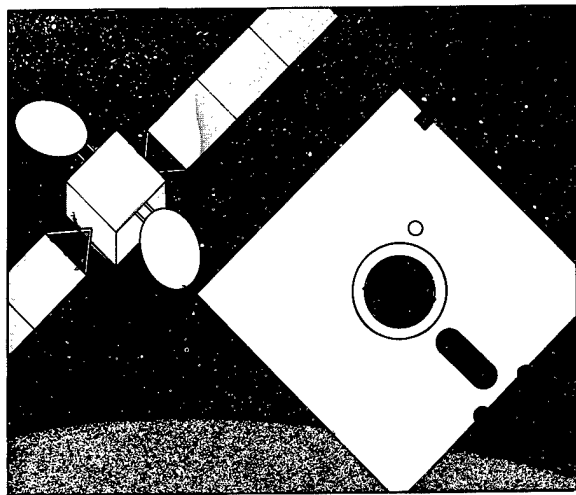
#### **3. Computer Software that Generates Commercial Electronic Circuitry Layouts**

Silicon Designs, Inc., a small high-tech business in Issaquah, Washington, has developed a software program with SDI SBIR funds that creates design layouts for integrated circuits (ICs) used in electronic microchips. Starting with software originally developed at Carnegie-Mellon University, Silicon Designs, Inc. has created a software program, called a module generator, that cuts the time and labor normally required to design ICs because it automates those steps required to draw intricate IC layouts by hand.

Silicon Designs' module generator was originally funded as part of an SDI SBIR project to design radiation-hard ICs for small, light-weight sensors and electronics that are resistant to destruction when exposed to intense radiation.

Using Silicon Design's module generator, designers can now create layouts for radiation-hard ICs at a development cost comparable to that of commercial non-radiation hard

IC designs. As a result, the scientist and engineer can now apply less labor-intensive techniques to design radiation-hard, lower-power electronic microchips for use in nuclear reactors, military systems, and nuclear physics



research. In addition, the module generator can be used to more easily convert some non-radiation hard microchip designs to radiation-hard configurations.

#### **4. Signal Processor Components for Optical Computers**

The Brimrose Corporation of America in Baltimore, Maryland, has developed a signal processor component that increases processing speed to 10 billion bits per second.

This component is a single element, two-dimensional, acousto-optic spatial light modulator (AOSLM) that is used for two-dimensional optical scanning, switching, and beam multiplication.

A direct spinoff from SDI SBIR research to develop a hybrid microcomputer-based optical signal processor using a two-dimensional AOSLM, this component is cheaper, uses less power, and has a greater bandwidth and resolution than modulators now on the market.

#### **5. Using Pictures to Develop Software Systems**

Integrated Systems, Inc. of Santa Clara, California, has designed a computer-aided software engineering (CASE) tool that generates detailed graphics, such as data flow diagrams, and the corresponding computer source code for design specifications. The CASE tool generates source code in FORTRAN, C, and ADA.

Using the CASE tool, the software engineer can construct a data flow diagram from which to develop the specification. The CASE tool can then be used to validate the software system's design as it is detailed in the specification. Once the specification has been validated,

the CASE tool automatically generates source code from the specification.

A direct spinoff from an SDI SBIR award to develop and test large software systems, Integrated Systems' CASE tool can be used in data acquisition, computer and process control, and system monitoring. The CASE tool also has applications for real-time signal processing and dynamic system simulations.

#### **6. Computer System Security Measures**

Odyssey Research Associates of Ithaca, New York, is developing specifications that permit computer security for linked computer systems to be controlled from any site, even though the linked systems are remote or off-site. Odyssey Research Associates' computer science and software engineering work in this area has applications for secure military databases and large secure commercial databases containing trade secrets, bank transactions, and billing or tax records. This work is a direct offshoot of SDI SBIR research done to develop a specification for secure distributed computer systems.

### **D. SDI SPINOFFS IN ENERGY**

#### **1. Introduction**

SDI research in semiconductors, superconductivity, and electromagnetic force is yielding spinoffs in a number of areas. These include energy-efficient semiconductor switches; superconducting, compact, and energy-efficient electronics; electromagnetic gun technology used in new defense systems; and materials used in heating systems

#### **2. Semiconductor Electronic Switching Device For Use in Electric Power Systems**

SDI research in high-power semiconductor switch technology has helped develop a device which has considerable commercial potential for use by the manufacturing community in power electronics systems. The metal oxide semiconductor-controlled thyristor (MCT) is an electronic switching device designed for electric power systems where high-speed, high-power control will enhance system efficiency and effectiveness. MCT research has been funded by SDIO, the National Aeronautics and Space Administration (NASA), the Defense Advanced Research Projects Agency (DARPA), the military services, General Electric Corporation, and the Electric Power Research Institute (EPRI).

MCT devices, expected to become commercially available this year, will be rated at 50 to 100 amperes up to 1000 volts. SDIO is currently sponsoring R&D for even higher power ranges with a goal of creating 2500 volt and 4500 volt, 100 to 200 ampere devices by 1991. These devices would be used in power conditioning, fault isolation, and regulation systems. MCTs are more rugged, reliable, efficient and versatile than conventional

semiconductor devices. Their ability to operate at higher temperatures can result in lighter weight packaging as well. Additionally, converting from direct current motor drives to all MCT adjustable speed motor drives could save as much as 30 percent of total system energy in some processes.

Potential applications include electric transportation propulsion, jet engine controls, lighting systems and variable speed motor drives. Automotive and other vehicle manufacturers have expressed interest in using MCT technology in electric drive automobiles and tanks because of the device's advantages over mechanical systems in terms of higher efficiencies in mileage per unit fuel and in weight savings. In addition, MCT technology could eliminate the need for mechanical transmissions in large, electric drive engines including those used in locomotives and industrial equipment.

### **3. Superconducting Device for Smaller, Faster, More Efficient Microwave Systems**

Investigators from the Sarnoff Research Center, Princeton, New Jersey, have taken thin-film superconducting material and used it to make microwave comb filters and delay lines that are hundreds of times more efficient than conventional circuits.

Bell Communications Research (Bellcore), Inc. of Red Bank, New Jersey, developed the superconducting material for the filter working with the Sarnoff group and scientists from Rutgers University on a contract from SDIO to design superconducting components and circuitry for space-based telecommunications, surveillance, and detection equipment that can operate at millimeter wavelengths.

Superconducting filters are faster and more powerful, efficient, and compact than equipment in use today. With a lower resistance than metal conductors, such superconductors can also be used in high-speed electronics to process large quantities of information more quickly than possible with the current state of technology. Superconductive materials also consume less power, thereby reducing the weight of material and components needed to transfer heat produced while the electronic circuitry and other devices are in use.

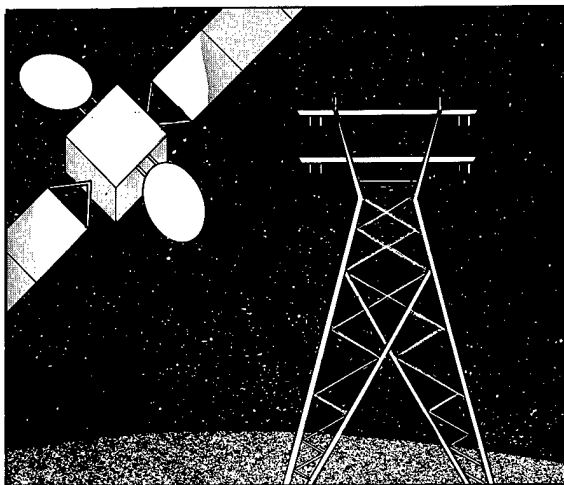
Such power-saving and electronic miniaturization developments could lead to significant reductions in the weight and volume of space-based communications systems, one-third of whose payload weight is made up of filters.

Commercial applications of this technology include telecommunications and microwave ovens.

### **4. SDI-Developed Electromagnetic Launch Technology Used in New Defense Systems**

Electromagnetic launch (EML) technology, originally conceived and tested under an SDI contract to the

Polytechnic University of Brooklyn, New York, is now being used to design electromagnetic energy tank guns that can potentially fire a projectile faster, further, and with more accuracy and lethality than conventional cannons. Other potential applications for the technology include its use in antimissile systems, naval artillery,



torpedo launchers, aircraft carrier catapults, and satellite launchers.

The barrel of an EML uses a series of pulsed coils to produce magnetic fields that propel the projectile toward its target. Because of the kinetic energy that can be generated by this technology, launchers designed on this principle provide a greater lethality than is achievable with present weapons.

### **5. Materials for Heating Systems**

Rasor Associates, Inc. of Sunnyvale, California, is manufacturing a product called K-Max that is made of material with exceptional heat transfer properties similar to those of heat pipes. Heat pipes, currently used in many satellite applications, are devices that transfer heat using physical properties rather than mechanical equipment. The K-Max material, developed from an SDI SBIR contract awarded to find ways to control the heat from space-based defense systems, conducts heat, can be formed into any shape, and hardens as a solid for use in building materials or manufacturing processes. While not a replacement for heat pipes, K-Max has applications where use of heat pipes would otherwise be considered too complex or inappropriate such as the development or manufacturing of intricate structures to transport heat a short distance or over a large area or path. Applications for this Rasor-developed material include its use in thermally-controlled blankets or garments or as a material to control or dissipate heat given off by spacecraft, motor vehicles, and electronic systems and components.

## E. SDI SPINOFFS IN ELECTRONICS

### 1. Introduction

SDI electronics research has been the source of a number of scientific, technical, and commercial innovations. These SDI spinoffs include electronics integrated into flow meters and magnetometers, laser technology used to design range finders and to micromachine integrated circuits, electronics that help analyze sensor images, advanced materials that improve sensor performance, and semiconductor electronics.

### 2. Electronics for Flow Meters and Magnetic Sensors

Silicon Designs, Inc. has developed miniature IC accelerometers and associated microprocessor interfacing electronics that increase the efficiency of measuring the flow rate of fluids in a pipeline. Developed with SDI SBIR funds to design sensors and electronics that are resistant to change when exposed to intense radiation, this IC's high-performance characteristics make it attractive for use as a baseline design for sensors that measure pressure and magnetic field strength. They can, for instance, be used to develop:

- Pressure transducers for refineries and chemical plants to monitor and meter the flow rate and pressure of liquids in pipelines.
- Solid-state magnetic sensors used in metal detectors and equipment designed for geophysical surveys. These magnetic sensors can also be used in mine fuses and magnetic compasses.

One Fortune 500 company, having tested the IC technology, is negotiating with Silicon Designs, Inc. to use the IC in its new line of commercial pressure sensors. Silicon Design's IC, when tested, was found to be thousands of times quieter and, thus, more effective than the IC the Fortune 500 company used at that time.

### 3. Laser Technology Used for Micromachining and Range-Finding Purposes

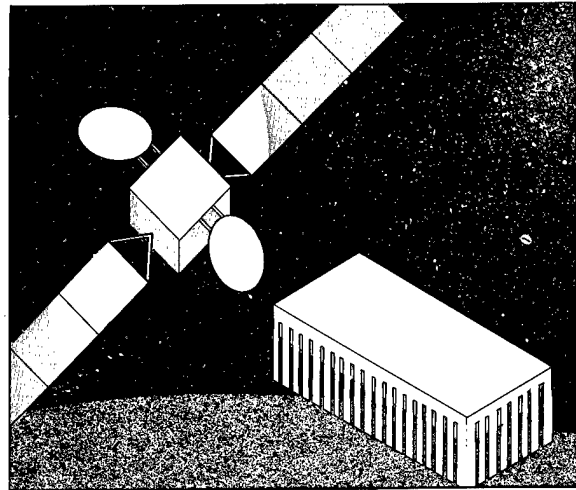
The Lightwave Electronics Corporation of Mountain View, California, has developed a laser-diode pumped, solid-state pulsed laser that is being sold to government contractors for use in laser range-finding systems. Industrial customers are also using the technology to produce ICs.

A direct spinoff from an SDI SBIR contract to find methods to take range measurements, this technology is a compact and efficient laser that generates short pulses of light from energy supplied by a super-efficient laser diode.

Applications for this technology include range-finding for geophysical, fiber-optic, and aviation uses and manufacturing microelectronics.

### 4. Advanced Materials Research that Improves Sensor Performance

Researchers from the Hughes Aircraft Company, Malibu, California, have developed a process to produce high-purity materials used to design and manufacture infrared detectors, ICs, and high-power switching devices. This project was originally funded through SDI to find ways to improve infrared detector performance. Impurities within



the material used to make the sensors can degrade their performance. Through research initiated with SDI funds, Hughes Aircraft researchers have developed a process which removes material impurities through the preparation of a high-purity silane gas. Using a purified silane gas, researchers can produce sensors that are more efficient.

The Union Carbide Corporation, under license from Hughes, is now marketing this silane purification process to produce ultra-high-purity silane gas. Electronics that can be manufactured with this technique are high-speed switches, long-wavelength infrared detectors, and high-power diodes.

### 5. Electronics that Help Analyze Sensor Images

Silicon Designs, Inc. has built and tested a high-performance, low-power voltage-to-frequency (V/F) converter that was originally spawned by an SDI SBIR contract to develop accelerometer electronic circuitry that is resistant to change when exposed to intense radiation. The accelerometer's high-performance characteristics made it attractive for use as a baseline design for a V/F converter that converts voltage signals to frequency signals which, for example, can be used in a digital electronic system such as a computer to analyze, manipulate, and enhance patterns and images picked up by the sensors.

This V/F converter is currently being modified for general-purpose commercial and military sensor applications. These applications include computers, security systems, and imagery-processing and enhancement

devices used by military and law enforcement personnel at night or in low-visibility conditions.

#### **6. Semiconductor Electronics with Industrial, Computer, and Automotive Applications**

The Kopin Corporation of Taunton, Massachusetts, is manufacturing silicon-on-insulator (SOI) wafers used in semiconductors based on SDI SBIR research it conducted to develop SOI wafers for radiation-hardened electronics. These Kopin-developed wafers, having widespread uses in the commercial marketplace, are currently being manufactured for several U.S. semiconductor and automotive companies that are developing high-performance electronic components with industrial, computer, automotive, and consumer applications. This technology, originally developed based on research done at MIT's Lincoln Laboratory, can also be used in sensors, memory circuits, high-temperature electronics, and high-voltage and radiation-hard circuits.

### **F. SDI SPINOFFS AND AEROSPACE INNOVATIONS**

#### **1. Introduction**

SDI research has been the source of numerous aerospace innovations that have been spun off to the U.S. public and private sectors. These spinoffs include new technologies incorporated into airport bomb detectors and instrumentation that tests missiles and rocket engines. SDI research has also been a source of innovation to develop a polymer materials process that makes lightweight, durable materials for space structures and technology designed to inspect rocket motors and aircraft engines for corrosion, internal damage, and structural defects.

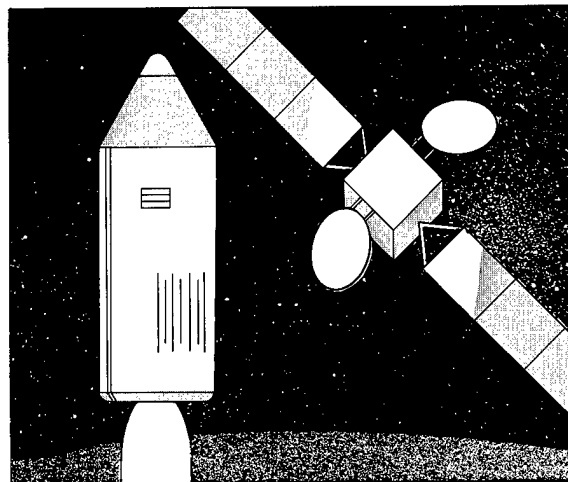
#### **2. Neutral Particle Beam Linear Accelerator (LINAC) Technology Used to Make Airport Bomb Detectors**

Linac technology developed at LANL in response to SDI requirements for a neutral particle beam source will now be used to improve airport bomb detectors. The Federal Aviation Administration has purchased an AccSys Technology, Inc. RFQ linac to evaluate the technology as a neutron source with which the bomb detector bathes luggage in low-energy neutrons. High nitrogen content explosives absorb the neutrons and emit a characteristic gamma radiation which can be detected by the scanners in the luggage screening system.

#### **3. Instrumentation to Test Missiles and Rocket Engines**

Aura Systems, Inc. has developed a magnetic suspension thrust test stand that is now being used by the U.S. Navy as an alternative to free-flight testing of missiles and rocket engines that have thrust pulses too fast for conventional stands to measure. New generations of propulsion systems have been developed that control the rocket's

flight path with greater accuracy by using thrusters that can achieve short thrust pulses of 10 milliseconds in duration. Engineers, using conventional test stands to test these new propulsion systems, find it difficult to measure thrust changes that are faster than 50 to 100 times per second. With this limitation in capability, conventional stands will not respond rapidly enough to the brief pulses of the new propulsion systems. The magnetic suspension thrust stand developed and produced by Aura to test SDI rocket thrusters can measure thrust at a response time short enough to measure the short pulses of the new thrusters. This stand is now being tested for use in U.S.



Navy conventional missile programs at the China Lake Naval Weapons Center, China Lake, California.

#### **4. Polymer Materials Process Used to Make Lightweight, Durable Space Structure Materials**

A polymer materials process originally developed through SDI SBIR research to manufacture large mirrors is now being used to make lightweight, durable materials for spacecraft structures. This process, developed by Foster-Miller, Inc. of Waltham, Massachusetts, lets the commercial innovator more precisely control such characteristics as the strength and stiffness of the material as well as the amount by which it expands under heat.

Space structure materials made from the polymer, poly p-phenylene benzobisthiazole (PBT), have been recorded as achieving weight savings of 50 percent or more over aluminum or graphite-epoxy materials now used in spacecraft structures. The PBT polymer, because of its stiffness and strength, has also proven to have excellent resistance to the extreme conditions of a space environment.

#### **5. Nondestructive Inspection of Rocket Motors and Aircraft**

AccSys Technology, Inc., has been awarded a U.S. Navy SBIR contract to develop equipment using the RFQ linac

as part of a nondestructive inspection system designed to inspect rocket motor components. This system could be used to detect propellant defects (voids, cracks, etc.) which can cause catastrophic destruction of rocket motors. Another possible application of this technology is being evaluated by the U.S. Navy for inspection of aircraft to reveal potential problems resulting from corrosion, internal damage, or structural defects.

## G. SDI SPINOFFS IN OPTICS

### 1. Introduction

SDI research in optics has yielded a number of spinoffs with scientific, technical, and commercial applications. These spinoffs include a high-resolution, wide-angle lens with applications for television and satellite navigational systems and a manufacturing process to make precision lenses and mirrors, and a synthetic diamond materials process used in optics.

### 2. Wide-Angle Lens That Produces Distortion-Free, High-Resolution Images

Researchers from Lawrence Livermore National Laboratory (LLNL), Livermore, California, and Perkin-Elmer Applied Optics Operations of Garden Grove, California, have produced a new wide-angle lens that makes possible the development of a new class of electronic optical systems that produce real-time, high-resolution images without distortion across a wide field of view. This lens was originally developed with SDI funds to design an electronic optical system capable of locating and tracking a large number of fast moving targets over a wide field of view.

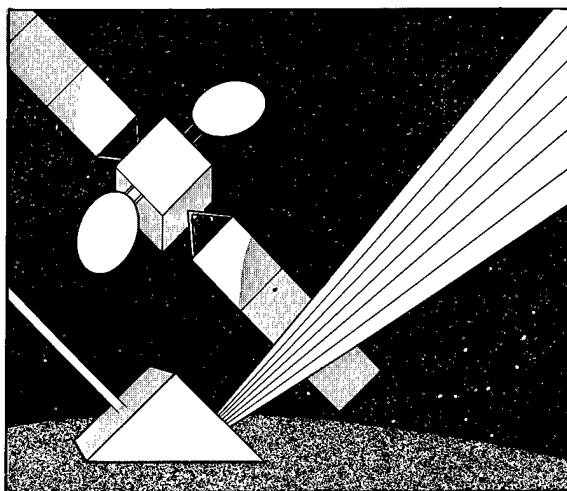
Camera designers have traditionally had to fight the problem of incompatible properties between the film and the lens. The film, for practical purposes, must lie flat in the back of the camera. By contrast, the focal surface of any simple lens is curved. Because of this incompatibility, designers must make compromises in the camera's setup to ensure that the camera gets an acceptable focus out to the edges of the image on a flat film or plate while controlling the various angular aberrations.

This newly developed wide-angle lens avoids this problem with a design that takes small charge-couple-device (CCD) image sensors similar to those found in television cameras and places them on a curved focal surface of constant radius. The resultant design produces a system whose symmetry eliminates angle-dependent aberrations.

Using LLNL's design concept, Perkin-Elmer produced a lens that is diffraction-limited over a 60-degree field of view and is fully color-corrected over the visible spectrum. This lens can also generate an image surface containing one to ten billion resolvable spots, which is hundreds of times better than the performance obtainable

with advanced photographic lenses currently available. Combining the wide-angle lens and CCD technology, researchers have developed a camera that provides high precision real-time imaging capabilities.

Prototypes of this camera are now being used to track meteors and satellites in space. Other applications being developed for this concept include its use in infrared cameras; satellite navigational systems; reconnaissance photography; security systems, and wide-angle, optical systems for television.



### 3. Manufacturing Process to Make Precision Lenses and Mirrors

University of New Mexico researchers have developed a new process to make lenses and mirrors with greater precision and accuracy. This process was developed based on SDI research originally funded to develop rapid cost-effective ion milling techniques to finish large, high-precision mirrors and optical surfaces. Researchers using this technique can create an ion beam to cut and finish lenses and mirrors with a precision of less than 1 micron (or one one-hundredth the thickness of a human hair).

With this technique, lenses, telescopes, and power laser tools can be manufactured with a greater accuracy than that provided by conventional optical milling techniques. Kodak, expressing interest in the commercial aspects of this process, has invested \$2 million of company R&D to further develop this technique.

### 4. An SDI Synthetic Diamond Manufacturing Process Used in Optics

Crystallume, Inc., a small business in Menlo Park, California, is commercializing a new SDI SBIR-funded manufacturing process to grow synthetic diamond films and coatings using chemical vapor deposition (CVD) techniques and marketing it to customers in the optics and medical communities. Combining characteristics normally associated with diamonds, such as strength,

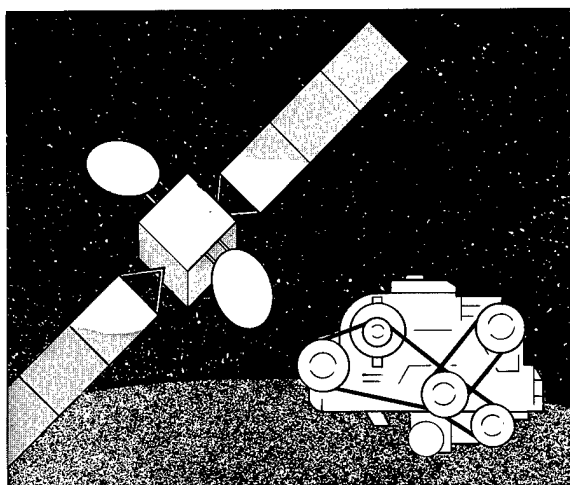


excellent heat conduction, impermeability, and x-ray transmission, this CVD process allows researchers to deposit synthetic diamonds on surfaces such as lenses, mirrors, and metal. This process, originally developed through SDI research to coat and protect mirrors, electronics, windows and lenses in space and other harsh environments, is being marketed by Crystallume as a corrosion-resistant, anti-erosion, and abrasion-resistant coating material that protects x-ray detectors, airborne optical systems, infrared sensors, microelectronic packaging, and optical systems used in laser surgery.

## **H. SDI SPINOFFS AND AUTOMOTIVE ENGINE COMPONENTS**

### **1. Introduction**

SDI research in materials science and the generation, transmission, and storage of power has produced spinoffs with applications for the automotive industry. These spinoffs include SDI materials used in automotive engine components and an efficient electrical generator that works without moving parts.



### **2. SDI Materials Used in Automotive Engine Components**

High-temperature ceramic materials originally developed through an SDI SBIR contract awarded to the Sullivan Mining Corporation of San Diego, California, for SDI space structures are now being evaluated for use in automobile engine components. The Chrysler Corporation, evaluating this material to make roller cam followers, has found that the Sullivan-developed material enables product simplification by eliminating 23 small bearings by constructing the roller of a single piece of carbon fiber ceramic material. Initial test results indicate this component is more durable than case-hardened steel now used to make the roller followers and should be less expensive to manufacture. Expanded testing of approximately 1,000 items will begin in 1990, leading to incorporation in the

Chrysler fleet, if successful.

### **3. An Efficient Electrical Generator Without Moving Parts**

Researchers from Argonne National Laboratory of Argonne, Illinois, using the results of SDI-funded fuel cell research, have developed an electrical generator without moving parts that uses gasoline, methane gas, or jet or diesel fuel with an efficiency of twice that of automotive engine generators now on the market. This generator, known as a monolithic solid oxide fuel cell (MSOFC), is built from solid-state ceramic electrolytes and electrodes and operates at around 1,000 degrees Celsius.

The MSOFC has been designed with the equivalent power density of a 20-pound, 65-horsepower generator that could power an automobile 60 miles an hour with an efficiency equivalent to 60 miles per gallon. Because the MSOFC operates more efficiently and generates less heat than conventional automotive generators, car engines equipped with this technology can also be redesigned with smaller radiators than are now used to dissipate the excess heat.

A direct spinoff from SDI research to develop a monolithic fuel cell, the MSOFC technology is currently being used in commercial operations at Allied Signal Aerospace of Torrance, California, and Combustion Engineering of Windsor, Connecticut. It is also being evaluated for use by power utilities.

## **I. SDI SPINOFFS AND INDUSTRIAL AND MANUFACTURING PROCESSES**

### **1. Introduction**

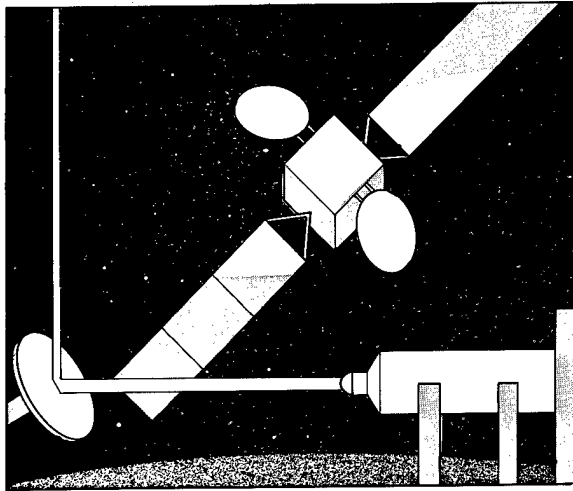
SDI research is providing a technology base to develop industrial and manufacturing processes of value to the nation. Such spinoffs include an industrial manufacturing process that casts parts and equipment for use in electronics, cars, satellites, spacecraft and a polymer materials process designed to make electronic circuit boards, and ceramic materials used in components and nuclear power plant fuels.

### **2. An Industrial Manufacturing Casting Process**

Researchers from MIT have developed a casting technique with SDI SBIR funds that is being further developed and commercialized by the P-Cast Equipment Company, Pittsburgh, Pennsylvania, as a manufacturing process to make meal-matrix parts and equipment for the electronics, automobile, and aerospace industries.

This MIT-developed casting procedure takes a pre-formed ceramic shape and injects it with a hot liquid metal matrix material to make hybrid equipment, components, and parts that take on both the high-temperature

characteristics of ceramics and the strength of metal. This technique uses a single vessel with precise control and monitoring of parameters to give the manufacturer more flexibility and control of the cast material's strength, density, thermal conductivity characteristics, and the amount at which it expands under heat. It is this flexibility and control which makes this casting technique so



promising a manufacturing process in comparison to conventional casting methods now on the market.

In contrast to conventional casting methods, this technique allows the manufacturer to control the temperature at which the casting materials are melted and the rate at which they solidify. With this process control, the manufacturer can get the casting material to solidify quickly, so it forms with a finer grain structure that adds to the material's strength.

This technique can also be used to cast materials in thin-walled molds. Taking advantage of this feature, materials can be cooled more quickly, allowing for greater flexibility in the development of new parts. Use of these molds also reduces the need for major retooling or capital investment in new presses or dies as would be required with other casting methods.

Applications for parts and equipment made with this casting process include electronics packaging, automotive engine parts, and satellite and spacecraft components.

### **3. Polymer Materials Process Used in Electronic Circuit Board Designs**

Under SDI SBIR sponsorship, Foster-Miller, Inc. developed a polymer materials process to manufacture large mirrors that is now being used to make electronic circuit boards. Electronic circuit boards made with the PBT polymer materials process lets the commercial innovator more precisely control such characteristics as the strength and stiffness of the material used to make the circuit board as well as the amount it expands under heat. Able

to control such characteristics, the innovator can use the process to make the thinly-layered materials for circuit boards used in the high-density wiring designs for very high speed integrated circuits developed to increase the speed with which computers process information.

### **4. Commercializing SDI-Developed Ceramic Materials**

Advanced Refractory Technologies (ART), Inc. of Buffalo, New York, is producing ceramic powder originally developed through SDI research that is being used to make pellets that extend the useful life of nuclear fuel and components for water jets, blasting nozzles, and body armor. Because this ceramic material, submicron boron carbide, comes in a powder form, it cuts the number of steps that in the past were required to mill and process the boron carbide for manufacturing purposes. This ART-developed ceramic powder also lets the manufacturer adopt molding techniques that work without pressure to mold components to a 97 plus percent density. Casting methods previously used to achieve this effect required hot pressing which limits the geometry and increases the production cost to manufacture small-sized components.

### **J. SUMMARY**

American technology is one of our most valuable national resources. In the coming year the best and brightest of our scientists and engineers will continue to unveil many new technology advances while working on SDI programs. As this report has summarized, these discoveries can be turned to other uses to help America to overcome some of our most challenging health, economic, and technical problems.

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